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[54] **METHODS AND DEVICES FOR JOINING TRANSMISSION COMPONENTS**

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[51] **Int. Cl.**^{7} **A61B 17/32**

[52] **U.S. Cl.** **606/169**; 604/22

[58] **Field of Search** 606/169, 170, 606/171; 604/22, 27

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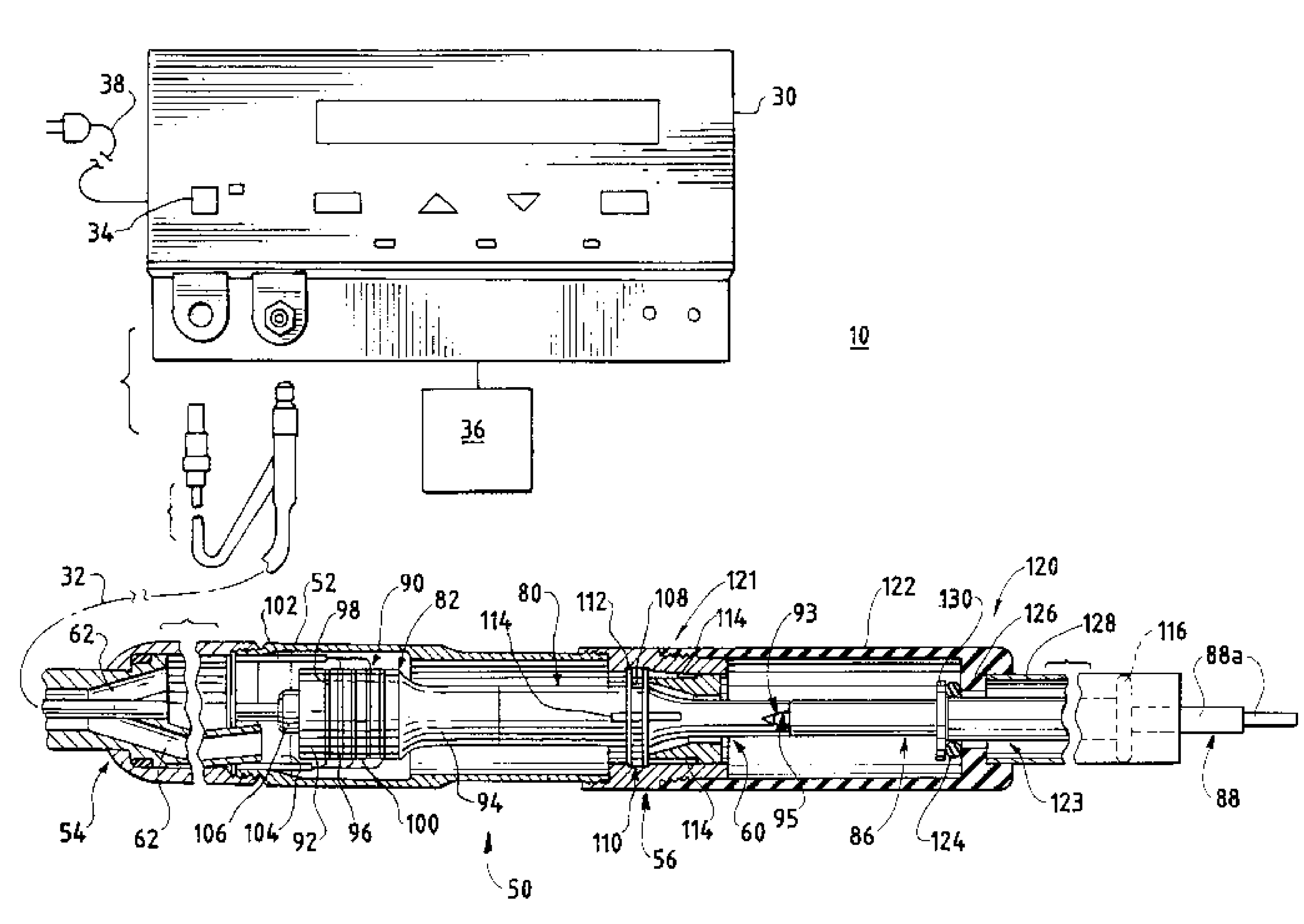
[57] **ABSTRACT**

A coupling structure releasably attaches a plurality of transmission members to each other. Non-vibratory structures hold a second end of the first transmission member in contact with a first end of the second member. A method including the steps of providing a first non-vibratory structure carrying the first transmission member, and providing a second non-vibratory structure carrying the second transmission member. The method also includes the steps of attaching the first non-vibratory structure to the second non-vibratory structure to hold a coupling end of the first transmission rod in contact with a coupling end of the second transmission rod without the use of a threaded connection between the first and second components.

22 Claims, 4 Drawing Sheets



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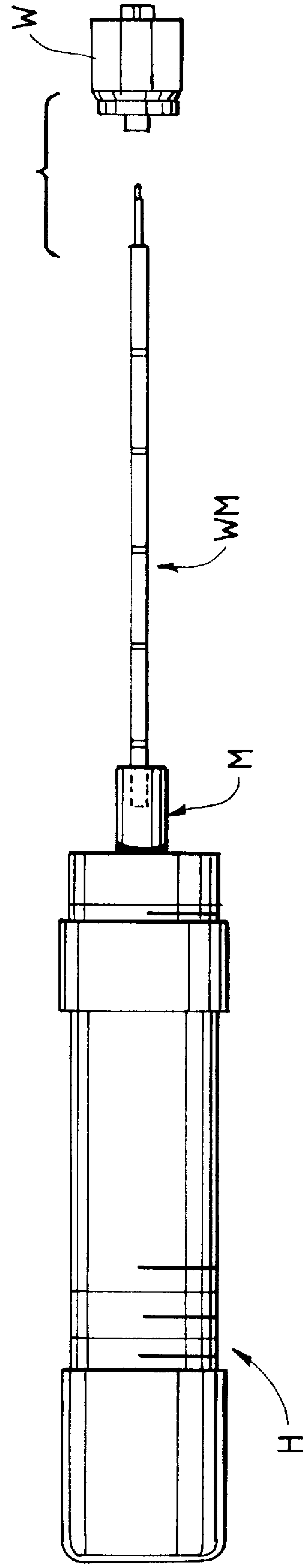

FIG. 1
PRIOR ART

FIG. 2

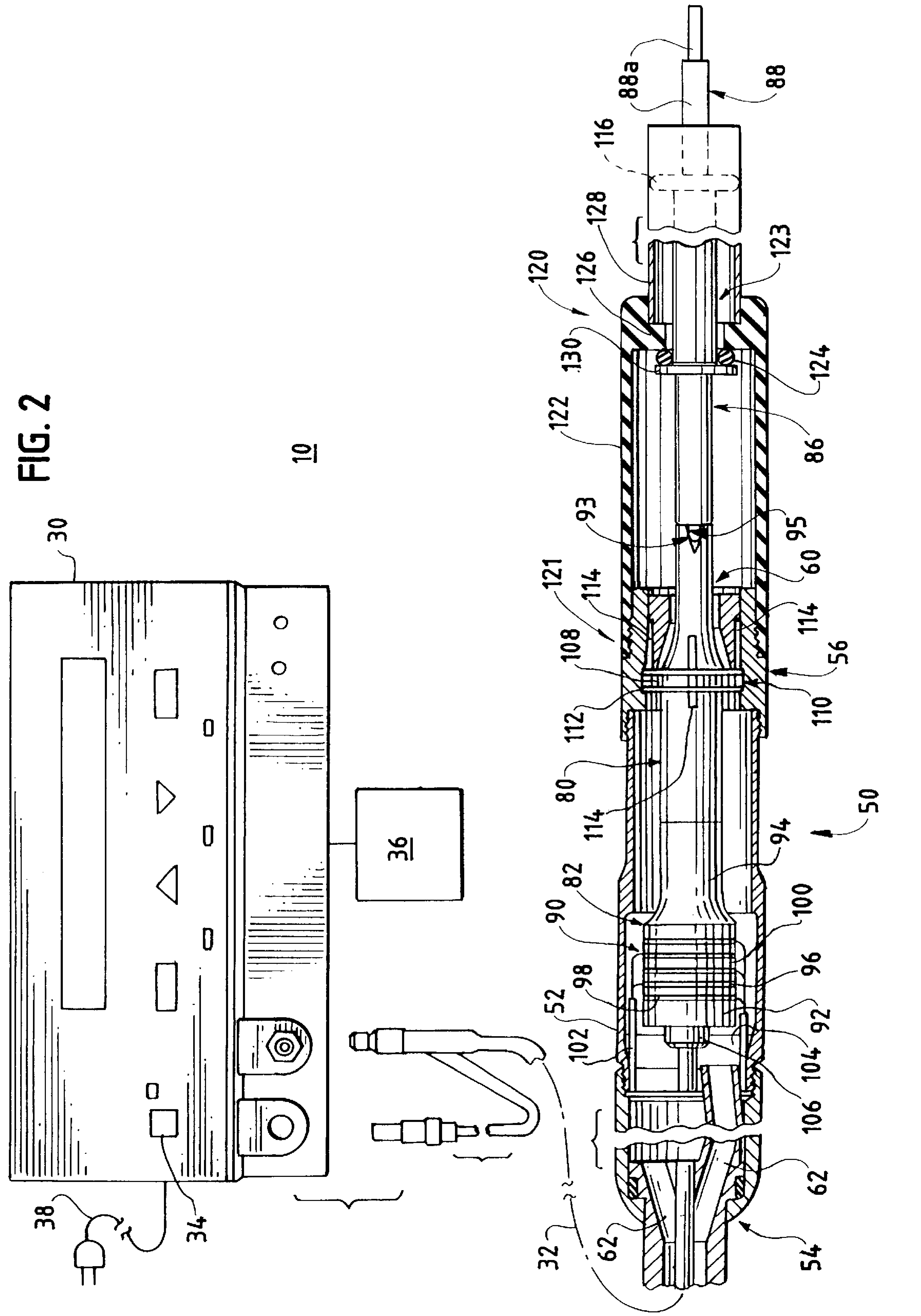
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FIG. 3

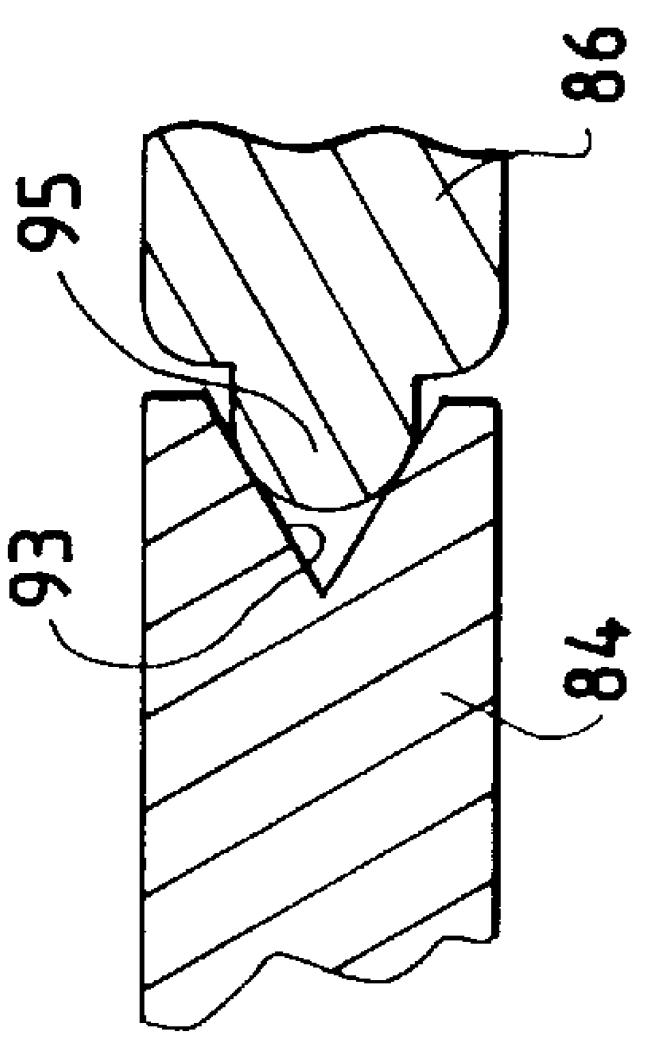
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FIG. 4

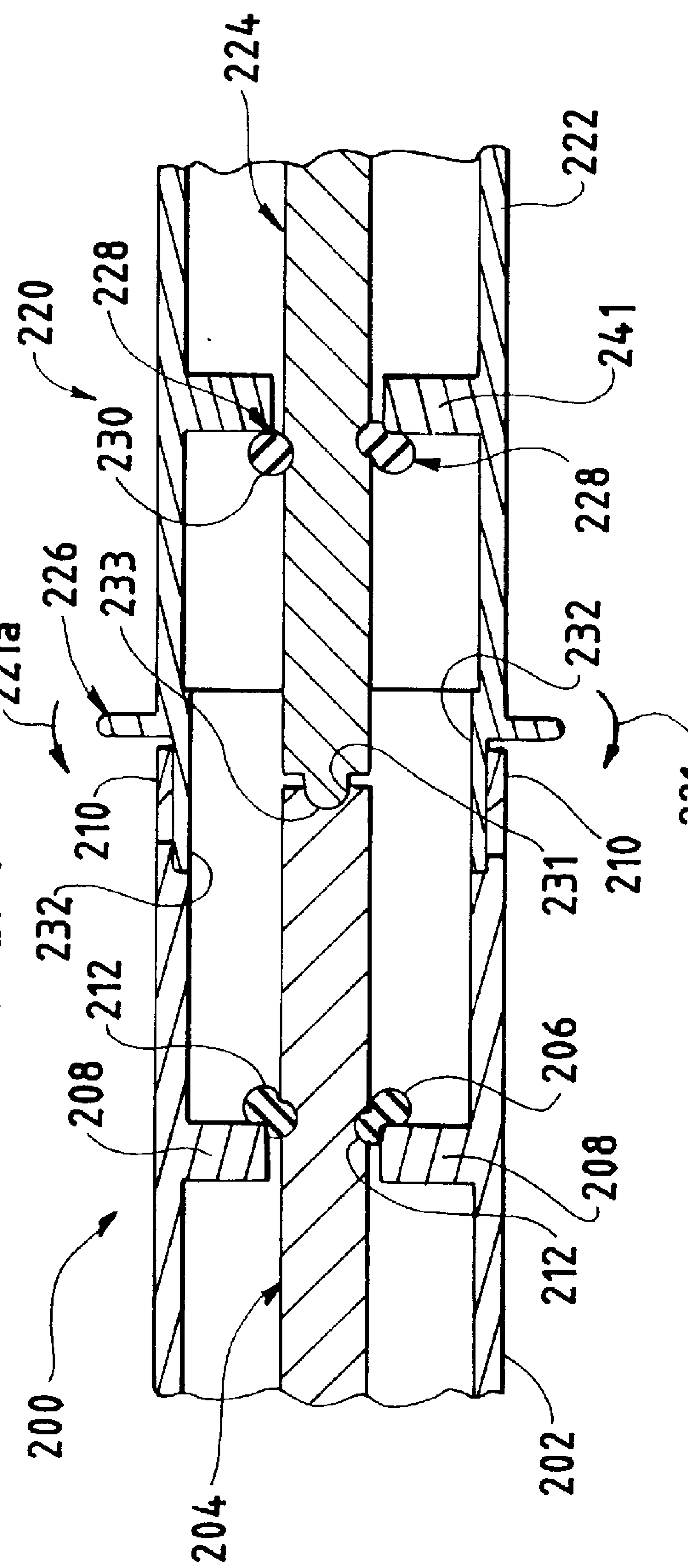
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FIG. 5

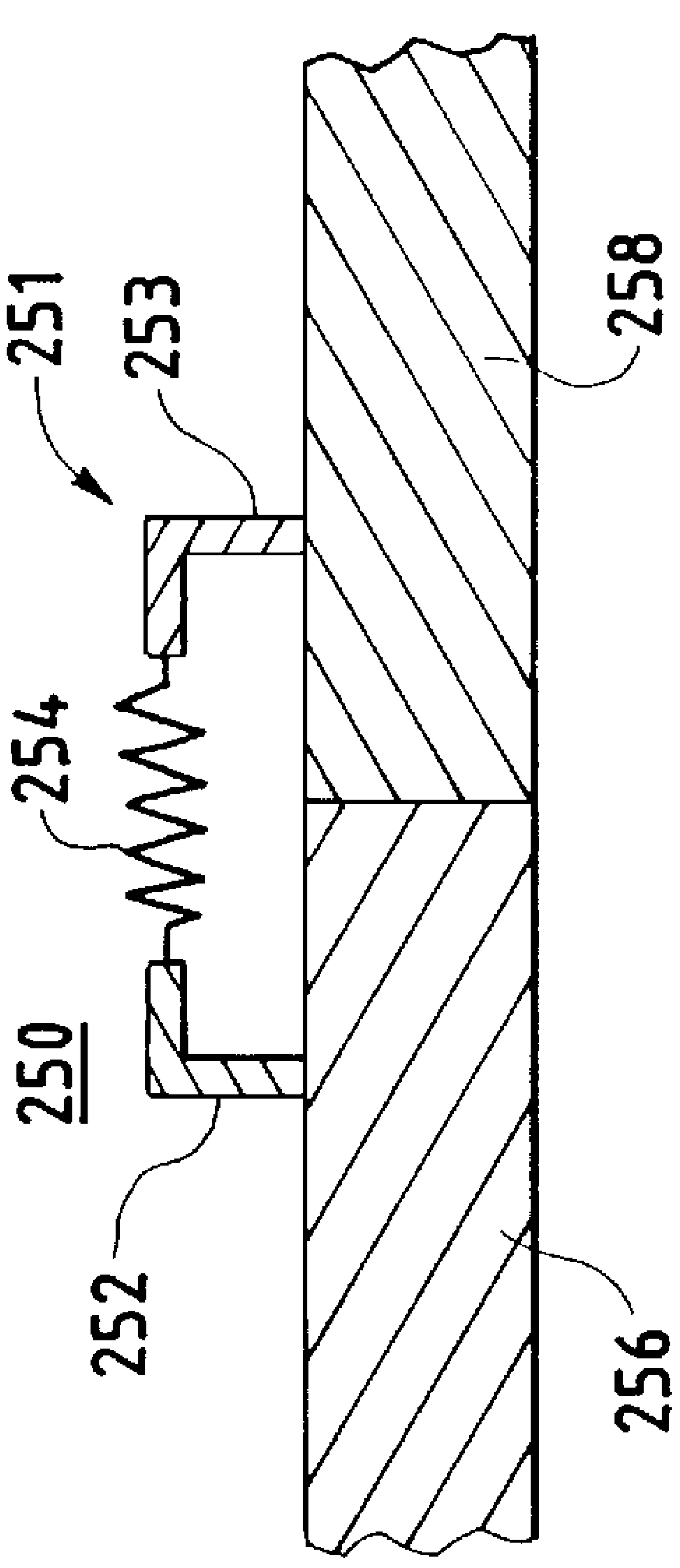
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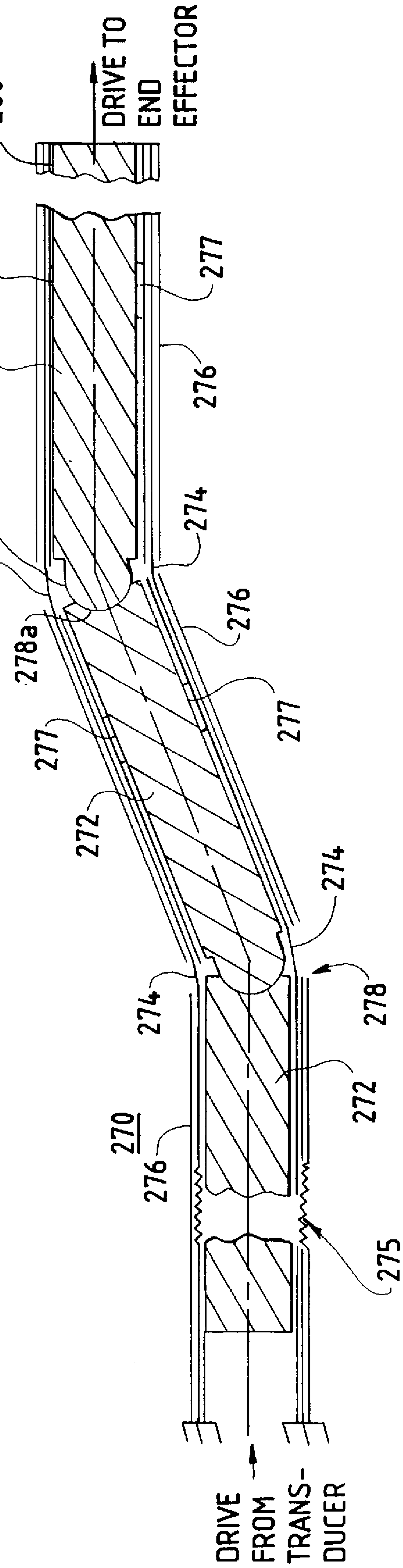
FIG. 6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DRIVE FROM TRANS-DUCER

METHODS AND DEVICES FOR JOINING TRANSMISSION COMPONENTS

FIELD OF THE INVENTION

The present invention generally relates to ultrasonic devices. More particularly, it relates to methods and devices for joining a plurality of ultrasonic transmission components by the use of one or more non-vibratory members which carry the ultrasonic transmission components.

BACKGROUND OF THE INVENTION

Ultrasonic transmission devices are frequently used in a variety of applications, such as surgical operations and procedures. Typically, these transmission devices usually include a transducer that converts electrical energy into vibrational motion at ultrasonic frequencies. The vibrational motion is usually transmitted through a transmission component, such as a mounting device, to vibrate a distal end of another transmission component, such as a working member.

The working member is usually attached to the mounting device by a threaded joint. In particular, the proximal end of the working member typically includes a threaded stud that is threaded into a threaded bore of the distal end of the mounting device. The tension between the threaded stud of the working member and the threaded bore of the mounting device provides an axial compression force to prevent the working member and mounting device from separating. However, the threaded bore and the threaded stud are usually costly to fabricate and are typically required to be manufactured within specific tolerance ranges. In addition, it can be difficult to manufacture threaded bores and threaded studs with small diameters.

The working member is usually tightened to the mounting device by using a tool, such a wrench. However, the use of as a wrench may cause the working member to be inadvertently over-tightened, which may tend to strip or damage the threads of the working member and mounting device. When the working member is over-tightened, the working member may be difficult to detach from the mounting device. On the other hand, insufficient tightening of the working member to the mounting device may cause undesired heat build-up of the threaded joints, decrease the transfer of energy across the junction, and cause unwanted transverse motion.

A torque limiting device may also be used to tighten the working member to the mounting device. The torque limiting device is used to assure that a predetermined minimum torque is reached and that a maximum torque is not exceeded when tightening the working member to the mounting device. In one known technique, a separate torque wrench W as illustrated in FIG. **1** may be placed over a working member WM to tighten and untighten the working member WM from a mounting device M of a surgical device. In this technique, the working member WM is attached to the mounting device M by a threaded connection. Once the working member WM is threaded onto the mounting device M, the torque wrench W is then slipped over the working member WM to tighten the working member WM to the mounting device M. A nose cone is then threaded onto the distal end of the handpiece assembly H.

However, it is quite difficult for a user to connect and disconnect the working member from the mounting device in a sterile field when using a separate torque wrench. Further, it may be cumbersome and time consuming to use a torque wrench when changing the working member during an operation or for tightening certain working members to the mounting device. Additionally, the torque wrench can be mislaid or lost and may require calibration or replacement at frequent intervals to ensure accuracy.

Accordingly, there is a need for improved devices and methods to join ultrasonic transmission components. Such devices would further benefit if the transmission components could be readily attached and detached without the use of a separate torque limiting device.

SUMMARY OF THE INVENTION

In view of the above, devices and methods are provided for attaching ultrasonic transmission components together in an operable arrangement without using a separate torque limiting device. The device allows the transmission components to be coupled together through a relatively small contact region and with relatively low coupling forces. The devices further allow transmission components having relatively small diameters to be coupled together. In general, the present invention contemplates use of one or more non-vibratory members for coupling ultrasonic transmission components carried by the non-vibratory members.

An ultrasonic device in accordance with the present invention includes a first transmission member and a second transmission member. A non-vibrating structure provides a preload force to hold an end of the first transmission member in contact with an end of the second member.

A method embodying the principles of the present invention includes the steps of providing a first non-vibratory structure carrying a first transmission member having a first end and a second end, and providing a second non-vibratory structure carrying a second transmission member having a first end and a second end. The method also includes the steps of attaching the first non-vibratory structure to the second non-vibratory structure to provide a preload force to hold one end of the first transmission rod in contact with an end of the second transmission rod without the use of a threaded connection between the first and second transmission members.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

The invention, together with attendant advantages, will best be understood by reference to the following detailed description of the preferred embodiments of the invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevational view of a prior art handpiece assembly of an ultrasonic device;

FIG. **2** is a fragmentary view and in partial cross-section of a first embodiment of a surgical system according to the present invention;

FIG. **3** is a fragmentary cross-sectional view of an interface between transmission components of the surgical system illustrated in FIG. **2**;

FIG. **4** is a fragmentary cross-sectional view of a second embodiment of a coupling arrangement between two ultrasonic transmission components;

FIG. **5** is a fragmentary cross-sectional view of another coupling arrangement between two ultrasonic transmission components; and

FIG. **6** is a cross-sectional view of an articulated ultrasonic waveguide.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before explaining the present invention in detail, it should be noted that the invention is not limited in its application or use to the details of construction and arrangement of parts illustrated in the accompanying drawings and description, because the illustrative embodiments of the invention may be implemented or incorporated in other embodiments, variations and modifications, and may be practiced or carried out in various ways. Furthermore, the terms and expressions employed herein have been chosen for the purpose of describing the illustrative embodiments of the present invention for the convenience of the reader and are not for the purpose of limitation.

FIG. **1** shows a side elevational view of a prior art handpiece assembly H. The working member WM is threaded onto the mounting device M. A torque wrench W is slipped over the working member WM to tighten the working member WM to a desired torque to the mounting device M.

Referring now to FIG. **2**, an embodiment of the surgical system **10** is illustrated. The surgical system **10** generally includes a generator **30**, a handpiece assembly **50**, an acoustic or transmission assembly **80**, and a surgical tool or instrument **120**. The generator **30** sends an electrical signal through a cable **32** at a selected amplitude, frequency, and phase determined by a control system of the generator **30**. As will be further described, the signal causes one or more piezoelectric elements of the acoustic assembly **80** to expand and contract, thereby converting the electrical energy into mechanical motion. The mechanical motion results in longitudinal waves of ultrasonic energy that propagate through the acoustic assembly **80** in an acoustic standing wave to vibrate the acoustic assembly **80** at a selected frequency and amplitude. An end effector **88** at the distal end of the acoustic assembly **80** is placed in contact with tissue of the patient to transfer the ultrasonic energy to the tissue. The cells of the tissue in contact with the end effector **88** of the acoustic assembly **80** will move with the end effector **88** and vibrate.

As the end effector **88** couples with the tissue, thermal energy or heat is generated as a result of internal cellular friction within the tissue. The heat is sufficient to break protein hydrogen bonds, causing the highly structured protein (i.e., collagen and muscle protein) to denature (i.e., become less organized). As the proteins are denatured, a sticky coagulum forms to seal or coagulate small blood vessels when coagulum is below 100° C. Deep coagulation of larger blood vessels results when the effect is prolonged.

The transfer of the ultrasonic energy to the tissue causes other effects including mechanical tearing, cutting, cavitation cell disruption, and emulsification. The amount of cutting as well as the degree of coagulation obtained varies with the vibrational amplitude of the end effector **88**, the amount of pressure applied by the user, and the sharpness of the end effector **88**. The end effector **88** of the acoustic assembly **80** in the surgical system **10** tends to focus the vibrational energy of the system **10** onto tissue in contact with the end effector **88**, intensifying and localizing thermal and mechanical energy delivery.

As illustrated in FIG. **2**, the generator **30** includes a control system integral to the generator **30**, a power switch **34**, and a triggering mechanism **36**. The power switch **34** controls the electrical power to the generator **30**, and when activated by the triggering mechanism **36**, the generator **30** provides energy to drive the acoustic assembly **80** of the surgical system **10** at a predetermined frequency and to drive

the end effector **88** at a predetermined vibrational amplitude level. The generator **30** may drive or excite the acoustic assembly **80** at any suitable resonant frequency of the acoustic assembly **80**.

When the generator **30** is activated via the triggering mechanism **36**, electrical energy is continuously applied by the generator **30** to a transducer assembly **82** of the acoustic assembly **80**. A phase lock loop in the control system of the generator **30** monitors feedback from the acoustic assembly **80**. The phase lock loop adjusts the frequency of the electrical energy sent by the generator **30** to match a preselected harmonic frequency of the acoustic assembly **80**. In addition, a second feedback loop in the control system maintains the electrical current supplied to the acoustic assembly **80** at a preselected constant level in order to achieve substantially constant vibrational amplitude at the end effector **88** of the acoustic assembly **80**. The electrical signal supplied to the acoustic assembly **80** will cause the distal end to vibrate longitudinally in the range of, for example, approximately 20 kHz to 100 kHz, and preferably in the range of about 54 kHz to 56 kHz, and most preferably at about 55.5 kHz. The amplitude of the acoustic vibrations at the end effector **88** may be controlled by, for example, controlling the amplitude of the electrical signal applied to the transduction portion **90** of the acoustic assembly **80** by the generator **30**.

As noted above, the triggering mechanism **36** of the generator **30** allows a user to activate the generator **30** so that electrical energy may be continuously supplied to the acoustic assembly **80**. In one embodiment, the triggering mechanism **36** preferably comprises a foot activating switch that is detachably coupled or attached to the generator **30** by a cable or cord. In another embodiment, a hand switch may be incorporated in the handpiece assembly **50** to allow the generator **30** to be activated by a user.

The generator **30** also has a power line **38** for insertion in an electrosurgical unit or conventional electrical outlet. It is contemplated that the generator **30** may also be powered by a direct current (DC) source, such as a battery. The generator **30** may be any suitable generator, such as Model No. GENO1 available from Ethicon Endo-Surgery, Inc.

Referring still to FIG. **2**, the handpiece assembly **50** includes a multi-piece housing or outer casing **52** adapted to isolate the operator from the vibrations of the acoustic assembly **80**. The housing **52** is preferably cylindrically shaped and is adapted to be held by a user in a conventional manner, but may be any suitable shape and size which allows it to be grasped by the user. While a multi-piece housing **52** is illustrated, the housing **52** may comprise a single or unitary component.

The housing **52** of the handpiece assembly **50** is preferably constructed from a durable plastic, such as Ultem®. It is also contemplated that the housing **52** may be made from a variety of materials including other plastics (i.e. high impact polystyrene or polypropylene). A suitable handpiece assembly **50** is Model No. HP050, available from Ethicon Endo-Surgery, Inc.

Referring still to FIG. **2**, the handpiece assembly **50** generally includes a proximal end **54**, a distal end **56**, and centrally disposed axial opening or cavity **58** extending longitudinally therein. The distal end **56** of the handpiece assembly **50** is coupled to the surgical instrument **120** and includes an opening **60** configured to allow the acoustic assembly **80** of the surgical system **10** to extend therethrough. The proximal end **54** of the handpiece assembly **50** is coupled to the generator **30** by a cable **32**. The cable **32** may include ducts or vents **62** to allow air to be introduced into the handpiece assembly **50** to cool the transducer assembly **82** of the acoustic assembly **80**.

The surgical instrument **120** of the surgical system **10** is preferably couplable to the distal end **56** of the handpiece assembly **50**. The surgical instrument **120** generally includes a housing or adapter **122**, a compliant support **124**, and a sheath or tubular member **128**. The proximal end **121** of the housing **122** of the surgical instrument **120** is threaded onto the distal end **56** of the handpiece assembly **50**. It is also contemplated that the surgical instrument **120** may be coupled to the handpiece assembly **50** by any suitable means, such as a snap-on connection or the like, without departing from the spirit and scope of the present invention.

The housing **122** of the surgical instrument **120** is preferably cylindrically shaped and has an opening **123** at its distal end **126** to allow the acoustic assembly **80** to extend therethrough. The housing **122** may be fabricated from Ultem®. It is contemplated that the housing **122** may be made from any suitable material without departing from the spirit and scope of the invention.

The sheath **128** of the surgical instrument **120** is attached to the distal end **126** of the housing **122**. The sheath **128** has an opening extending longitudinally therethrough. The sheath **128** may be fabricated from stainless steel or any other suitable material. Alternatively, polymeric material may surround the transmission rod **86** to isolate it from outside contact.

Referring still to FIG. **2**, the acoustic assembly **80** generally includes a transducer stack or assembly **82**, a mounting device **84**, a transmission rod or waveguide **86**, and an end effector or applicator **88**. The transducer assembly **82**, mounting device **84**, a transmission rod **86**, and the end effector **88** may be acoustically tuned such that the length of each component is an integral number of one-half system wavelengths ($N\lambda/2$) where the system wavelength λ is the wavelength of a preselected or operating longitudinal vibration frequency f of the acoustic assembly **80**. It is also contemplated that the acoustic assembly **80** may incorporate any suitable arrangement of acoustic elements. For example, the acoustic assembly **80** may comprise a transducer assembly and an end effector (i.e., the acoustic assembly **80** may be configured without a mounting device and a transmission rod). In one embodiment, the transducer **82** and mounting device **84** are carried by the handpiece assembly **50**, and the transmission rod **86** and end effector **88** are carried by the surgical instrument **120**.

The transducer assembly **82** of the acoustic assembly **80** converts the electrical signal from the generator **30** into mechanical energy that results in longitudinal vibrating motion of the end effector **88** at ultrasonic frequencies. When the acoustic assembly **80** is energized, a vibratory motion standing wave is generated through the acoustic assembly **80**. The amplitude of the vibratory motion at any point along the acoustic assembly **80** depends on the location along the acoustic assembly **80** at which the vibratory motion is measured. For example, a minimum or zero crossing in the vibratory motion standing wave is generally referred to as a node (i.e., where axial motion is usually minimal and radial motion is usually small), and an absolute value maximum or peak in the standing wave is generally referred to as an antinode. The distance between an antinode and its nearest node is one-quarter wavelength ($\lambda/4$).

As shown in FIG. **2**, the transducer assembly **82** of the acoustic assembly **80**, which is known as a "Langevin stack", generally includes a transduction portion **90**, a first resonator **92**, and a second resonator **94**. The transducer assembly **82** is preferably an integral number of one-half wavelengths system ($N\lambda/2$) in length. It is to be understood that the present invention may be alternatively configured to include a transducer assembly comprising a magnetostrictive, electromagnetic or electrostatic transducer.

The distal end the first resonator **92** is connected to the proximal end of the transduction section **90**, and the proximal end of the second resonator **94** is connected to the distal end of the transduction portion **90**. The first and second resonators **92** and **94** are preferably fabricated from titanium, aluminum, steel, or any other suitable material. The first and second resonators **92** and **94** have a length determined by a number of variables, including the thickness of the transduction section **90**, the density and modulus of elasticity of material used in the resonators **92** and **94**, and the fundamental frequency of the transducer assembly **82**. The second resonator **94** may be tapered inwardly from its proximal end to its distal end to amplify the ultrasonic vibration amplitude.

The transduction portion **90** of the transducer assembly **82** preferably comprises a piezoelectric section of alternating positive electrodes **96** and negative electrodes **98**, with piezoelectric elements **100** alternating between the electrodes **96** and **98**. The piezoelectric elements **100** may be fabricated from any suitable material, such as lead zirconate, lead titanate, or ceramic crystal material. Each of the piezoelectric elements **100**, negative electrodes **98**, and positive electrodes **96** may have a bore extending through the center. The positive and negative electrodes **96** and **98** are electrically coupled to wires **102** and **104**, respectively. The wires **102** and **104** transmit the electrical signal from the generator **30** to electrodes **96** and **98**.

As shown in FIG. **2**, the piezoelectric elements **100** are held in compression between the first and second resonators **92** and **94** by a bolt **106**. The bolt **106** preferably has a head, a shank, and a threaded distal end. The bolt **106** is inserted from the proximal end of the first resonator **92** through the bores of the first resonator **92**, the electrodes **96** and **98**, and piezoelectric elements **100**. The threaded distal end of the bolt **106** is screwed into a threaded bore in the proximal end of second resonator **94**.

The piezoelectric elements **100** are energized in response to the electrical signal supplied from the generator **30** to produce an acoustic standing wave in the acoustic assembly **80**. The electrical signal causes disturbances in the piezoelectric elements **100** in the form of repeated small displacements resulting in large compression forces within the material. The repeated small displacements cause the piezoelectric elements **100** to expand and contract in a continuous manner along the axis of the voltage gradient, producing high frequency longitudinal waves of ultrasonic energy. The ultrasonic energy is transmitted through the acoustic assembly **80** to the end effector **88**.

The mounting device **84** of the acoustic assembly **80** has a proximal end, a distal end, and may have a length substantially equal to an integral number of one-half system wavelengths. The proximal end of the mounting device **84** is preferably axially aligned and coupled to the distal end of the second resonator **94** by an internal threaded connection near an antinode. It is also contemplated that the mounting device **84** may be attached to the second resonator **94** by any suitable means, and that the second resonator **94** and mounting device **84** may be formed as a single or unitary component.

The mounting device **84** is coupled to the housing **52** of the handpiece assembly **50** near a node. (For purposes of this disclosure, the term "near" is defined to mean "exactly at" or "in close proximity to".) The mounting device **84** may also include an integral ring **108** disposed about its periphery. The integral ring **108** is preferably disposed in an annular groove **110** formed in the housing **52** of the handpiece assembly **50** to couple the mounting device **84** to the housing **58**. A compliant member or material **112**, such as a pair of silicon O-rings attached by standoffs, may be placed between the annular groove **110** of the housing **52** and the integral ring **108** of the mounting device **84** to reduce or prevent ultrasonic vibration from being transmitted from the mounting device **84** to the housing **52**.

The mounting device **84** may be secured in a predetermined axial position by a plurality of pins **114**, preferably four. The pins **114** are disposed in a longitudinal direction **90** degrees apart from each other around the outer periphery of the mounting device **84**. The pins **114** are coupled to the housing **52** of the handpiece assembly **50** and are disposed through notches in the integral ring **108** of the mounting device **84**. The pins **114** are preferably fabricated from stainless steel.

The mounting device **84** is preferably configured to amplify the ultrasonic vibration amplitude that is transmitted through the acoustic assembly **80** to the distal end of the end effector **88**. In one preferred embodiment, the mounting device **84** comprises a solid, tapered horn. As ultrasonic energy is transmitted through the mounting device **84**, the velocity of the acoustic wave transmitted through the mounting device **84** is amplified. It is contemplated that the mounting device **84** may be any suitable shape, such as a stepped horn, a conical horn, an exponential horn, or the like.

The distal end of the mounting device **84** is configured to interface or engage with the proximal end of the transmission rod **86**. As shown in FIG. **3**, the distal end of the mounting device **84** preferably has a mating or coupling surface **93** that is axially aligned with a mating or coupling surface **95** of the proximal end of the transmission rod **86**. The mating surface **93** of the mounting device **84** has a non-threaded cavity or bore that is substantially conically or wedge shaped. It is also contemplated that the mating surface **93** of the mounting device **84** be formed as a convex or partially curved surface.

The mating surface **95** of the transmission rod **86** has a non-threaded axially extending member or projection. The mating surface **95** is preferably substantially spherically shaped. It is contemplated that the surfaces **93,95** could be interchanged. For example, the mounting device **84** may have a non-threaded projection at its distal end and the transmission rod **86** may have a non-threaded cavity at its proximal end. Other suitable mating surfaces having different non-threaded surfaces could be used without departing from the spirit and scope of the present invention. The mating surfaces **93,95** of the mounting device **84** and transmission rod **86** may also be coated with titanium nitride (TiN) to improve wear life.

The mating surface **93** of the mounting device **84** and the mating surface **95** of the transmission rod **86** are forced together axially so that the junction or point of contact is preferably near an antinode. Preferably, a minimal contact area exists between the mating surfaces **93,95**. A coupling force between the mating surfaces **93,95** is created when the handpiece assembly **50** is coupled to the surgical instrument **120**. The handpiece assembly **50** and the surgical instrument **120** are preferably coupled near a vibrational antinode because it is the point of minimum stress and therefore requires the least preload force.

The mating surfaces **93,95** of the transmission rod **86** and the mounting device **84** provide a socket arrangement which is self-aligning and self-centering. The socket arrangement also allows slight non-axial alignment of the transmission rod **86** and the mounting device **84**. The contact region or area between the mating surfaces **93,95** efficiently transfers mechanical or ultrasonic vibration across the junction between them. The contact region between the mating surfaces **93,95** has a relatively small area. As a result, a moderate or relatively low preload force can hold the transmission rod **86** and the mounting device **84** together. For example, because of the shape of the interacting surfaces **93,95**, an axial pre-load force between 5–25 pounds may be sufficient to hold the mounting device **84** and transmission rod **86** together. This is a lower force than is often required to reliably couple together threaded ultrasonic elements.

Referring again to FIG. **2**, the transmission rod **86** includes a support or retention member. The retention member preferably includes an integral ring or flange **130** disposed around its periphery. It is also contemplated that the retention member may include a number of suitable configurations, such as an O-ring fixedly attached to a groove or the periphery of the transmission rod **88**.

A compliant member **124** is preferably positioned between the integral ring **130** of the transmission rod **86** and the distal end **126** of the housing **122** of the surgical tool **120**. The compliant member **124** preferably isolates the housing **122** of the surgical instrument **120** from the ultrasonic vibrations of the transmission rod **86**. The compliant member **124** is preferably an O-ring fabricated from silicone or polyterafluroethylene (PTFE) and having a low spring rate (i.e., k rate (k)). In an alternative embodiment, the compliant member **124** preferably consists of a thin layer of compliant material with a high or low k rate on a conventional metal or plastic coil or disk spring.

The compliant member **124** preferably contacts the transmission rod **86** at a plane perpendicular to the axis of the transmission rod **86** to provide a compression force perpendicular to the radial motion near or at the node to minimize the loss of ultrasonic power caused by the vibration of the compliant member **124**. This configuration also allows the transmission rod **86** to be rotated relative to the handpiece assembly **50** without removing it or loosening the connection between the handpiece assembly **50** and the surgical instrument **120**.

To couple the surgical instrument **120** to the handpiece assembly **50**, the surgical instrument **120** is preferably threaded onto the distal end **56** of the handpiece assembly **50** bringing the mounting surface **95** of the transmission rod **86** into communication or contact with the mounting surface **93** of the mounting device **84**. Alternate arrangements, such as a twist-lock fitting, are also within the spirit and scope of the present invention.

When the surgical instrument **120** is attached to the handpiece assembly **50**, the compliant member **124** is compressed to create an attachment force or preload force. The compliant member **124** preferably has a low spring rate (k) to provide a preload force of contact between the mounting device **84** and the transmission rod **86** that is substantially the same regardless of the tolerances of the components or the manner that the surgical instrument **120** is attached to the handpiece assembly **50**. It is contemplated that the surgical instrument **120** may be attached to the handpiece assembly

50 by any suitable means, such as, for example, a threaded or snap-on connection, to compress the compliant member, such as, for example, springs, O-rings and the like, to create the preload force.

Referring again to FIG. **2**, the transmission rod **86** of the acoustic assembly **80** may have a length substantially equal to an integer number of one-half system wavelengths ($N\lambda/2$). The transmission rod **86** is preferably fabricated from a solid core shaft constructed out of material which propagates ultrasonic energy efficiently, such as titanium alloy (i.e., Ti-6A1-4V) or an aluminum alloy. As those skilled in the art will recognize, the transmission rod **86** may be fabricated from other suitable materials. The transmission rod **86** may also amplify the mechanical vibrations transmitted through the transmission rod **86** to the end effector **88** as is well known in the art.

The transmission rod **86** includes stabilizing silicone rings or compliant supports **116** (one being shown) positioned at a plurality of nodes. The silicone rings **116** dampen undesirable vibration and isolate the ultrasonic energy from a sheath **128** of the surgical instrument **120** assuring the flow of ultrasonic energy in a longitudinal direction to the distal end of the end effector **88** with maximum efficiency.

The distal end of the transmission rod **86** is coupled to the proximal end of the end effector **88** by an internal threaded connection, preferably near an antinode. It is contemplated that the end effector **88** may be attached to the transmission rod **86** by any suitable means, such as a welded joint or the like. Although the end effector **88** may be detachable from the transmission rod **86**, it is also contemplated that the end effector **88** and transmission rod **86** may be formed as a single unit.

The end effector **88** may have a distal region **88*b*** having a smaller cross-section area than a proximal region **88*a*** thereof, thereby forming a vibrational amplitude step-up junction. The step-up junction acts as velocity transformer as known in the art, increasing the magnitude of the ultrasonic vibration transmitted from the proximal region **88*a*** to the distal region **88*b*** of the end effector **88**.

The end effector **88** may have a length substantially equal to an integral multiple of one-half system wavelengths ($N\lambda/2$). The distal tip of the end effector **88** is disposed at an antinode where the maximum longitudinal deflection occurs. When the transducer assembly **82** is energized, the distal end of the end effector **88** is configured to move longitudinally in the range of 10 to 500 microns peak-to-peak, and preferably in the range of 30 to 100 microns at a predetermined vibrational frequency, and most preferably at about 90 microns.

The end effector **88** is preferably made from a solid core shaft constructed of material which propagates ultrasonic energy, such as a titanium alloy (i.e., Ti-6A1-4V) or an aluminum alloy. As those skilled in the art will recognize, the end effector **88** may be fabricated from other suitable materials. The distal end of the end effector **88** may be any suitable shape to transfer the ultrasonic energy to the tissue of a patient. It is also contemplated that the end effector **88** may have a surface treatment to improve the delivery of energy and desired tissue effect. For example, the end effector **88** may be micro-finished, coated, plated, etched, grit-blasted, roughened or scored to enhance coagulation in tissue. Additionally, the end effector may be shaped to enhance its energy transmission characteristics. For example, the end effector **88** may be blade shaped, hook shaped, or ball shaped.

Referring now to FIG. **4**, another embodiment of a coupling arrangement between a first ultrasonic device **200** and a second ultrasonic device **220** is illustrated. The first ultrasonic device **200** generally includes a housing or sheath **202**, a transmission component or member **204**, and an elastomeric or compliant material **206**. The housing **202** of the first ultrasonic device **200** preferably includes an inwardly projecting ring **208** and coupling members **210**. The housing **202** preferably surrounds the transmission member **204** to isolate the transmission component **204** from contact by a user.

The housing **202** of the first ultrasonic device **200** is preferably cylindrically shaped. It is contemplated that the housing **202** may be any suitable configuration without departing from the spirit and scope of the invention. The housing **202** may be constructed from any suitable material, preferably Ultem®.

The second ultrasonic device **220** generally includes a housing or sheath **222**, a transmission component or member **224**, a release mechanism **226**, and a elastomeric or compliant material **228**. The housing **222** of the second ultrasonic device **220** preferably includes an inwardly projecting ring **230** and coupling members **232**. The housing **222** preferably surrounds the transmission component **224** to isolate the transmission member **224** from contact by a user.

The housing **222** of the second ultrasonic device **220** is preferably cylindrically shaped. It is contemplated that the housing **222** may be any suitable configuration. The housing may also be fabricated from any suitable material, preferably Ultem®.

The housings **202,222** of the first and second ultrasonic devices **200,220** are couplable to each other by the coupling members **210,232**. The coupling members **210,232** preferably comprise interlocking members to secure the housings **202,222** together. Preferably, the coupling members **210,232** snap together when the housings **202,222** are slid together axially. It is contemplated that the housings **202,222** may be attached by any suitable releasable latching or locking mechanism. The housings **202,222** may be disconnected by pressing the release mechanism **226** while pulling the housings **202,222** apart. When the release mechanism **222** is pressed in the direction of arrows **221*a***, the release mechanism **222** disconnects the coupling members **210,232**.

The transmission members **204,224** of the first and second ultrasonic devices **200,220** preferably have mating surfaces or regions **231,233** that are adapted to be brought into communication or contact with each other, preferably near or at an antinode. The mating surfaces or regions **231,233** are substantially similar to the mating surfaces of the transmission rod **86** and the mounting device **84** as described above. As such, further description of the mating surfaces **231,233** of the transmission members **204,224** are unnecessary for a complete understanding of this embodiment.

The compliant members **206,228** each comprise an O-ring that is located in grooves **212** and **241** disposed about the periphery of each transmission member **204,224**. The compliant members **206,228** are attached to the grooves **212,241** by mechanical interference or an adhesive. In one preferred embodiment, the compliant members **206,228** are secured to the transmission components **206,228** by the adhesion of silicone created by a molding process as is known in the art. The compliant members **206,228** position and support the transmission members **204,224** within the housings **202,232** to reduce the conduction of vibration into the housings **202,232** and minimize energy loss due to heating or noise.

When the ultrasonic devices **200,220** are coupled to each other, a preload force is created between the transmission members **204,224** by the compliant members **206,228** which are compressed or stretched elastically. It is also contemplated that although the support structure is illustrated as an external element, it could be located within a lumen within the transmission members **204,224**. For example, the transmission member **204** may be inserted into a lumen of the transmission member **224** and held together by a press fit or floating pin.

Referring now to FIG. **5**, another embodiment of a coupling arrangement **250** for joining ultrasonic transmission components is illustrated. The coupling arrangement **250** generally includes a non-vibrating structure support (generally indicated at **251**), a first transmission component or member **256**, and a second transmission component or member **258**. The non-vibrating structure **251** preferably includes a first portion **252**, a second portion **253**, and a coupling mechanism **254** for generating a preload force. The first portion **252** of the non-vibrating structure is preferably resiliently coupled to the first transmission component **256** near a node, and the second portion **253** of the non-vibrating structure is resiliently coupled to the second transmission component **258** near a node. The first portion **252** and second portion **253** are isolated from the transmission components **256,258** by compliant support material.

The first and second transmission components **256,258** are joined to or held together near an antinode to minimize the preload force required to hold them together. The coupling mechanism **254** generates sufficient preload force to couple the transmission components **256,258** together. The coupling mechanism **254** may be provided by any suitable mechanism, such as springs, living snaps, pneumatics, magnetic, suction/vacuum from an operating room, mechanical over center toggle, ¼ turn threaded fitting, and the like.

Referring now to FIG. **6**, a preferred embodiment of an articulated or flexible ultrasonic transmission or waveguide assembly **270** is illustrated. The waveguide assembly **270** includes a plurality of transmission components or members **272**, tension wires **274**, a spring or adjustable tensioner **275**, a tube-like sheath or tension wire guide **276** that surrounds the transmission components **274**, and elastomeric attachments **277**.

The adjacent ones of the transmission components **272** are joined or held together near an antinode of vibration. The transmission components **272** each have a mating surface or region **278***a* and **278***b* that is substantially similar to the mating surfaces of the transmission members **204,224** described above. As such, further description of the mating surface **278** of the transmission components **272** is unnecessary for a complete understanding of this embodiment.

The tension wire **275** of the waveguide assembly **270** extends through the tension wire guide. The tension wire **275** provides a force to create a substantially uniform contact force between the mating surfaces **278***a* and **278***b* of the transmission components **272** when tightened. The tension wires **275** may be tightened or loosened through the adjustable tensioner **275** in order to change the angles between the transmission components **274**, allowing the waveguide assembly **270** to be configured in a desired shape. The transmission component **272** may be positioned in a wide range of connected angles with respect to each other. The waveguide assembly **270** may be attached or coupled to another transmission component **280**.

The methods and devices of present invention allow transmission components to be joined without using an external torque limiting device. Adjacent ones of the transmission components are joined together near or at an antinode. The transmission components are maintained in contact by a preloaded force created by a non-vibrating structure. The area of contact between the transmission components may be relatively small and the transmission components may also have relatively small diameters.

Although the present invention has been described in detail by way of illustration and example, it should be understood that a wide range of changes and modifications can be made to the preferred embodiments described above without departing in any way from the scope and spirit of the invention. Thus, the described embodiments are to be considered in all aspects only as illustrative and not restrictive, and the scope of the invention is, therefore, indicated by the appended claims rather than the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. An ultrasonic surgical device comprising:

a transducer assembly adapted to vibrate at an ultrasonic frequency in response to electrical energy;

a mounting device having a first end and a second end, the mounting device having a length which is substantially equal to an integral number of one-half wavelengths of the ultrasonic frequency, the mounting device being adapted to receive the ultrasonic vibration from the transducer assembly and to transmit the ultrasonic vibration from the first end to the second end of the mounting device, the first end of the mounting device being coupled to the transducer assembly near an antinode;

a transmission rod having a first end and a second end, the transmission rod having a length which is substantially equal to an integral multiple of one-half wavelengths of the ultrasonic frequency, the transmission rod being adapted to receive the ultrasonic vibration from the mounting device and to transmit the ultrasonic vibrations from the first end to the second end of the transmission rod, the first end of the transmission rod being coupled to the second end of the mounting device by a non-threaded interface near an antinode; and

an end effector having a first end and a second end, the end effector being adapted to receive the ultrasonic vibrations from the transmission rod and transmit the vibrations from the first end to the second end of the end effector; the first end of the end effector being coupled to the second end of the transmission rod, and the second end of the end effector being disposed near an antinode.

2. The device of claim **1** wherein the second end of the mounting device includes a non-threaded cavity.

3. The device of claim **1** wherein the first end of the transmission rod has a non-threaded projection.

4. The device of claim **1** further comprising a handpiece assembly coupled to the mounting device near a node of vibration.

5. The device of claim **4** wherein one end selected from the first end of the transmission rod and the second end of the mounting rod includes a cavity, wherein the other end selected therefrom includes a projection projecting into the cavity, and wherein the device further comprises at least one compliant member arranged to force the projection into the cavity, so as to define the non-threaded interface.

6. The device of claim **5** wherein the first end of the transmission rod includes the cavity and wherein the second end of the mounting rod includes the projection.

7. The device of claim **4** wherein the first end of the transmission rod includes a substantially conically or wedge-shaped cavity, wherein the second end of the mounting rod includes a projection projecting into the cavity and mating with the first end of the transmission rod wherein the device further includes a compliant member positioned at the second end of the transmission rod and arranged to force the projection into the cavity, so as to define the non-threaded interface.

8. The device of claim **7** wherein the projection is substantially spherical where mating with the first end of the transmission rod.

9. The device of claim **1** further comprising an adapter coupled to the transmission rod near a node of vibration.

10. The device of claim **9** wherein one end selected from the first end of the transmission rod and the second end of the mounting rod includes a cavity, wherein the other end selected therefrom includes a projection projecting into the cavity, and wherein the device further comprises at least one compliant member arranged to force the projection into the cavity, so as to define the non-threaded interface.

11. The device of claim **10** wherein the first end of the transmission rod includes the cavity and wherein the second end of the mounting rod includes the projection.

12. The device of claim **9** wherein the first end of the transmission rod includes a substantially conically or wedge-shaped cavity, wherein the second end of the mounting rod includes a projection projecting into the cavity and mating with the first end of the transmission rod wherein the device further includes a compliant member positioned at the second end of the transmission rod and arranged to force the projection into the cavity, so as to define the non-threaded interface.

13. The device of claim **12** wherein the projection is substantially spherical where mating with the first end of the transmission rod.

14. The device of claim **1** further comprising a generator to energize the transducer assembly.

15. The device of claim **14** wherein one end selected from the first end of the transmission rod and the second end of the mounting rod includes a cavity, wherein the other end selected therefrom includes a projection projecting into the cavity, and wherein the device further comprises at least one compliant member arranged to force the projection into the cavity, so as to define the non-threaded interface.

16. The device of claim **15** wherein the first end of the transmission rod includes the cavity and wherein the second end of the mounting rod includes the projection.

17. The device of claim **14** wherein the first end of the transmission rod includes a substantially conically or wedge-shaped cavity, wherein the second end of the mounting rod includes a projection projecting into the cavity and mating with the first end of the transmission rod wherein the device further includes a compliant member positioned at the second end of the transmission rod and arranged to force the projection into the cavity, so as to define the non-threaded interface.

18. The device of claim **17** wherein the projection is substantially spherical where mating with the first end of the transmission rod.

19. The device of claim **1** wherein one end selected from the first end of the transmission rod and the second end of the mounting rod includes a cavity, wherein the other end selected therefrom includes a projection projecting into the cavity, and wherein the device further comprises at least one compliant member arranged to force the projection into the cavity, so as to define the non-threaded interface.

20. The device of claim **19** wherein the first end of the transmission rod includes the cavity and wherein the second end of the mounting rod includes the projection.

21. The device of claim **1** wherein the first end of the transmission rod includes a substantially conically or wedge-shaped cavity, wherein the second end of the mounting rod includes a projection projecting into the cavity and mating with the first end of the transmission rod wherein the device further includes a compliant member positioned at the second end of the transmission rod and arranged to force the projection into the cavity, so as to define the non-threaded interface.

22. The device of claim **21** wherein the projection is substantially spherical where mating with the first end of the transmission rod.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,051,010

DATED : April 18, 2000

INVENTOR(S) : Stephen Dimatteo, et al.

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

In claim 1, line 22, kindly insert --detachably-- after "coupled".

Signed and Sealed this

Twenty-seventh Day of March, 2001

Attest:

Nicholas P. Godici

NICHOLAS P. GODICI

Attesting Officer

Acting Director of the United States Patent and Trademark Office